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GAMMA RADIATION-INDUCED TRANSFORMATIONAL CHANGE IN IR SPECTRUM OF EBHA NEMATIC LIQUID CRYSTAL

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ABSTRACT

Gamma ray irradiation technique is the powerful technique to modify the dielectric and electro-optical properties of liquid crystals. It prefers than any other modification technique because no catalysts or additives are required to initiate the reaction. The present paper reports a comparative study of IR spectrum for both irradiated and unirradiated EBHA NLC. The dielectric spectrum and ionic conductivity is also evaluated and well explained in this paper. In addition to this, we have also suggested the concept of the peak data information graph for better understanding of IR spectrum.

Key words: Nano Materials, Condensed Matter Physics, Gamma Radiation, Dielectric, IR Spectrum

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1. INTRODUCTION

Radiation materials science describes the interaction of radiation with matter. A broad subject covering many forms of irradiation and of matter. The consequences of radiation to core components includes changes in shape and volume by tens of percent, increases in hardness by factors of five or more, severe reduction in ductility

and increased embrittlement, and susceptibility to environmentally induced cracking. For these structures to fulfill their purpose, a firm understanding of the effect of radiation on materials is required in order to account for irradiation effects in design, to mitigate its effect by changing operating conditions, or to serve as a guide for creating new, more radiation-tolerant materials that can better serve their purpose [1].

The phenomenon of gamma radiation induced conductivity in solid insulators has been studied by several investigators. Most attention has been given to studies of organic insulators [2–4], and some have been made of inorganic insulators [5–7]. Up to now, only few reports were dedicated to radiation effects on physicochemical properties and on the conductivity of the liquid crystals materials [8]. Data regarding radiation effects on liquid crystal and organo-photonic material is almost non-existent [9].

Preliminary studies on some liquid crystals suggest that their physical and chemical properties are highly affected by radiation. Most of these suggest that the transition temperatures and the stability of various liquid crystalline mesophases are strongly affected by radiation [10]. Some of the electrical properties such as electrical conductivity and charge carrier mobility subjected by ionizing radiation have been studied very first in 1988 by Kovalchuk et al. [11]. Talor et al. first reported on the degradation of light transmission characteristics of a smectic C liquid crystal [12]. Graham et al. also reported on the effect of space radiation dose on the nematic liquid crystal variable retarders (LCVR) [13]. Such other radiation effects on the liquid crystal materials namely electron beam radiation, UV radiation, ion beam radiation has also been reported [14].

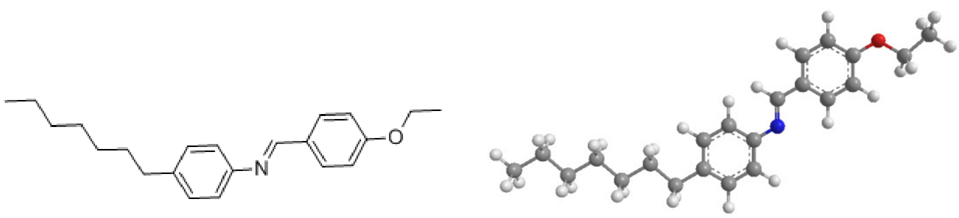
Absorption of gamma rays by liquid crystal may cause physical conformational changes due to thermal and thermo-mechanical effects. These physical changes may cause scattering of light, changes in transmission and reflection properties of filters and coatings. Early liquid crystal phase retarders were screened at Raytheon for radiation sensitivity circa 1989 under the AFRL Beam agility technique program (F33615-87-1507). Phase retarders were used as surrogates for optical phased arrays and subjected to increasing gamma ray dose from a cobalt-60 source, upto a total dose of 9.5 Mrad. It was the first known radiation testing of liquid crystal [15].

In the present paper we have reported the variation in IR spectra of a nematic liquid crystal caused by gamma radiation. In addition to this we have also evaluated the dielectric spectrum for both gamma irradiated and unirradiated EBHA NLC.

2. EXPERIMENTAL DETAILS

2.1. Material Used

The liquid crystal sample under investigation is a rod shaped nematic liquid crystal molecule. The structure and its phase transition behavior are given in the Figure 1.



P-ETHOXYBENZYLIDENE P-HEPTYLANILINE

Cr→52^{0}C N→85^{0}C Iso

Figure 1 Chemical structure with transition scheme for EBHA nematic liquid crystal.

2.2. Preparation of cell

Two similar cells having active areas 25 mm^2, (sheet resistance and the visible light transmission is 10Ω/mm^2 and more than 90% respectively) were prepared by using transparent and highly conducting ITO (Indium Tin Oxide) (Diamonds Coating UK) coated optically flat glass substrates used as electrodes. These electrodes give a base to the LC sample to align. Planar alignment is obtained by treating both adhesion promoter and polymer (Nylon 6/6) and then rubbed unidirectional with a velvet cloth. Although the homeotropic cell has been prepared by applying lecithin on the ITO coated surface. The thickness of the cell was maintained at 5 μm by means of Mylar spacer. The complete preparation of cell has been given in our earlier papers [16]. The correct and proper alignment of the LC molecules is extremely important, for precise measurement of electrical properties and which in turn influences dielectric parameters and thus plays an extremely important role in molecular geometry.

2.3. Gamma Ray treatment

We have irradiated the EBHA NLC. The irradiation used a ^{60}Co source, at the dose rate of 2.9 kGy/h, up to a total dose for 34.5 h is 100 kGy.

2.4. Dielectric study

The dielectric behavior of the material has been studied by using a computer controlled impedance/ gain phase analyzer Hewlett Packard (HP 4194 A). The dielectric parameters have been measured as a function of temperature and frequency. In order to vary the temperature of the sample holder a microprocessor based heating device Instec hot plate (HCS-302) with an accuracy of ± 0.01^0C has been used. Before taking measurements the sample was left for 15 minutes at a particular temperature.

The Threshold voltage measurement has also been done by using the same computer controlled impedance/ gain phase analyzer Hewlett Packard (HP 4194 A). The dielectric permittivity has been measured as a function of voltage.

2.5. FT-IR Study

FTIR measurements are carried out using IRAffinity-1 (Shimadzu) Fourier Transform Infrared Spectrophotometer. The measurements have been done in the wave number range 500–4000 cm^{-1}, keeping air as reference.

3. RESULT AND DISCUSSION

Due to the wealth of information that FT-IR spectroscopy provides on molecular state, orientation, and dynamics, it has often been used to characterize liquid crystals and liquid crystal systems. Moreover, it has been observed that the IR spectrum of a liquid crystal system depends on its phase (isotropic or mesogenic) [17]. Thus, in addition to the dependence on concentration, the IR spectra of liquid crystalline system have a significant dependence on their director alignment and molecular phase, which is controlled by temperature for thermotropic liquid crystals.

In this way the radiated and unirradiated samples are analyzed by FT-IR spectroscopy. The FT-IR spectrum for the unirradiated and gamma irradiated EBHA nematic liquid crystal is shown in Figure 2.

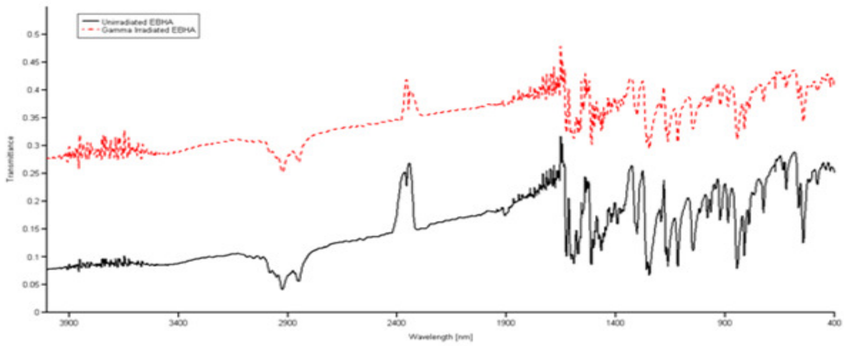


Figure 2 Variation in transmittance with respect to wavelengthfor EBHA NLC

For better understanding of the IR spectra, assignments of the major peaks of the liquid crystal material are shown in peak data information (PDI) graphs. The PDI graphs for the unirradiated and gamma irradiated liquid crystalline materials have been shown in Figure 3. Using PDI graphs FT-IR study suggests that up to given dose of gamma radiation, the liquid crystal system causes chemical change which is responsible for shifting of absorption peaks. Which is responsible for variation in transmittance as shown in figure. Figures also suggest the gamma irradiated EBHA NLC exhibit a high transmittance as compared with unirradiated EBHA NLC.

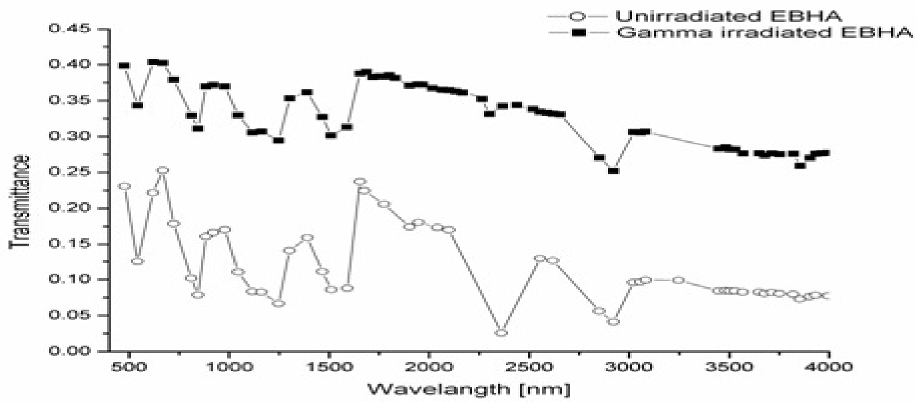


Figure 3 PDI graph for EBHA NLC

When the frequency of a specific vibration is equal to the frequency of the IR radiation directed to the molecule, the molecule absorbs the radiation. The total number of observed bands is generally different from the total number of fundamental vibrations. It is reduced because some modes are not IR active and a single frequency can cause more than one mode of motion to occur. Conversely additional bands are generated by the appearance of overtones, combination of fundamental frequencies, coupling interactions of two fundamental absorption frequencies. Thus we can say that the shifting of absorption peaks is due to the gamma induced physic-chemical change in liquid crystal molecule. In this way the dielectric response of the sample with frequency has been taken (Figure 4).

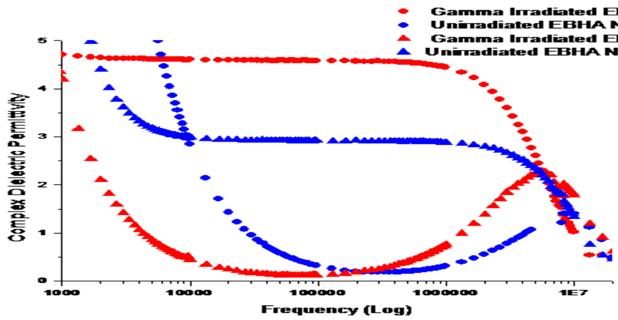


Figure 4 Complex dielectric permittivity with variation in frequency

The observed value of complex dielectric permittivity for both irradiated and unirradiated EBHA NLC, nature of variation with frequency is same, but the values have increased for gamma irradiated EBHA NLC sample. Actually irradiation causes a chemical change in liquid crystalline materials, it may include cross linking, chain scission, formation of alkyl groups, depletion of hetero atoms. Effect of gamma irradiation or such other ionizing radiation is primarily chain scission. Therefore many physical and chemical properties can show modification with gamma irradiation. Radiation mainly affects in two basic ways, both resulting with excitation or ionization of atoms. In this fashion ionic conductivity of liquid crystal material has also been investigated and shown in figure 5.The ionic conductivity for irradiated EBHA NLC sample is comparatively higher than that of unirradiated EBHA NLC sample.

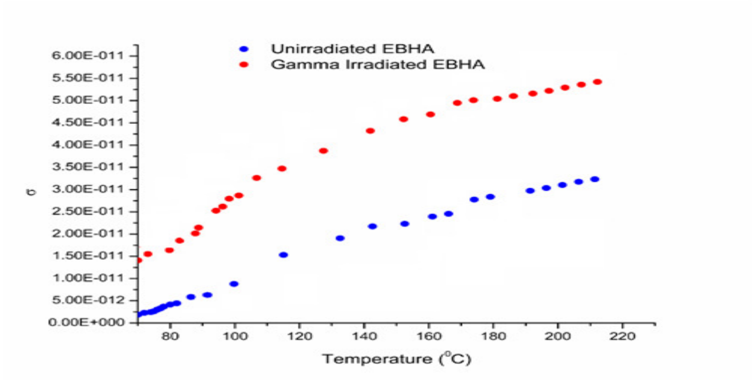


Figure 5 Variation in ionic conductivity of EBHA NLC caused by gamma radiation

4. CONCLUSION

We observe that the nature of variation of dielectric permittivity with frequency and temperature remains same for both the gamma irradiated and the unirradiated EBHA samples, but the value of dielectric permittivity for the gamma irradiated sample is higher as compared to the unirradiated EBHA sample. This increment in the gamma irradiated sample can be explained on the basis of physicochemical change in the EBHA molecules due to irradiation. Also the effect of gamma irradiation on EBHA NLC sample has been evaluated using FT-IR. New concept of PDI graph has been shown for better understanding of IR spectra.

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